standard rating does not fall within this range.

6.3.4 Operation and Maintenance of Electrical Systems

6.3.4.1 The designer shall specify that building owners be provided with written information that provides basic data relating to the design, operation, and maintenance of the electrical distribution system for the building. This shall include:

6.3.4.1.1 a single-line diagram of the ''as-built'' building electrical system;

6.3.4.1.2 schematic diagrams of electrical control systems (other than HVAC, covered elsewhere);

6.3.4.1.3 manufacturers' operating and maintenance manuals on active electrical equipment; and

6.3.4.1.4 the Transformer Loss Calculation Estimate if required by Section 6.3.2.2.

§ 435.107 Heating, Ventilation, and Air-Conditioning (HVAC) systems.

7.1 General

7.1.1 This section contains minimum and prescriptive requirements for the design of HVAC systems. It is recommended that the designer evaluate other energy conservation measures that may be applicable to the proposed design.

7.1.2 A building shall be considered in compliance with this section if the following conditions are met:

7.1.2.1 The minimum requirements of Section 7.3 are met; and

7.1.2.2 The HVAC system design complies with the prescriptive criteria of section 7.4. For the design of HVAC systems that incorporate innovative or alternate design strategies, the compliance paths set forth in Section 11.0 or 12.0 should be used.

7.2 Principles of Design

7.2.1 Control of Equipment Loads

7.2.1.1 The thermal impact of equipment and appliances shall be minimized by use of hoods, radiation shields, or other confining techniques, and by use of controls to assure that such equipment is turned off when not needed. In addition, major heat-generating equipment shall, where practical, be located where it can balance other heat losses. For example, computer centers or kitchen areas could be located in the north or northwest perimeter areas of buildings depending on climate and prevailing wind directions. In addition, heat recovery shall be specifically considered for this equipment.

7.2.2 HVAC System Design

7.2.2.1 Separate HVAC systems shall be considered to serve areas expected to operate on widely differing operating schedules or design conditions. For instance, systems serving office areas should generally be separate from those serving retail areas. When a single system serves a multi-tenant building, provisions shall be made to shut-off or set-back the heating and cooling to each area independently.

7.2.2.2 Spaces with relatively constant and weather-independent loads may be served with systems separate from those serving perimeter spaces. Areas with special temperature or humidity requirements, such as computer rooms, shall be served by systems separate from those serving areas that require comfort heating and cooling only, alternatively, these areas shall be served by supplementary or auxiliary systems.

7.2.2.3 The supply of zone cooling and heating shall be sequenced to prevent the simultaneous operation of heating and cooling systems for same space. Where this is not possible due to ventilation or air circulation requirements, air quantities shall be reduced as much as possible before reheating, recooling, or mixing hot and cold air streams. Finally, supply air temperature shall be reset to extend economizer operations and to reduce reheat, recool, or mixing losses.

7.2.2.4 Systems serving areas with significant internal heat gains (lighting, equipment, and people), especially interior zones with little or no exposure to outside air, shall be designed to take advantage of mild or cool weather conditions to reduce cooling energy if heat recovery systems are not used. These systems, called air or water economizers, shall be designed to provide a partial reduction in cooling loads even when mechanical cooling must be used to provide the remainder of the load. Economizer controls shall be integrated with the mechanical cooling (leaving air temperature) controls so that mechanical cooling is only operated when necessary and so supply air is not overcooled to a temperature below the desired supply temperature. The systems and controls shall be designed so that economizer operation does not increase heating energy use. For instance, single fan dual duct or multizone systems that use the same mixed air plenum for both heating and cooling supplies shall not be used.

7.2.2.5 Controls shall be provided to allow systems to operate in an occupied mode and an unoccupied mode. In the occupied mode, controls shall provide for a gradually changing control point as system demands change from cooling to heating. In the unoccupied mode, ventilation and exhaust systems shall be shut off if possible, and comfort heating and cooling systems shall be shut off except to maintain ''setback'' space conditions. The setback conditions shall be the minimum and maximum levels required to prevent damage to the building or its contents and provide for a reasonable morning pick-up period. Note however that night setback may not conserve energy in buildings with large amounts of thermal mass.

7.2.2.6 In areas where diurnal temperature swings and humidity levels permit, the judicious coupling of air distribution systems and building structural mass may be considered to allow the use of night-time precooling to reduce the use of day-time mechanical cooling.

7.2.2.7 High ventilation, such as in hospital operating rooms, can impose enormous heating and cooling loads on HVAC equipment. In these cases, consideration shall be given to the use of recirculating filtered and cleaned air, rather than 100% outside air, and preheating outside air with solar systems or reclaimed heat from other sources.

7.2.3 Energy Transport Systems

7.2.3.1 Energy shall be transported by the most energy efficient means possible. The following options, are listed in order of efficiency from the (most efficient) lowest energy transport burden to the highest:

7.2.3.1.1 Electric Wire or Fuel Pipe,

7.2.3.1.2 Two-Phase Fluid Transfer (Steam or Refrigerant),

7.2.3.1.3 Single-Phase Liquid Fluid (Water, Glycol, Etc.), and

7.2.3.1.4 Air.

7.2.3.2 The distribution system shall be selected to complement other system parameters such as control strategies, storage capabilities, and conversion and utilization system efficiencies.

7.2.3.3 Steam Systems

7.2.3.3.1 Provisions for seasonal or ''non-use time'' shutdown shall be incorporated.

7.2.3.3.2 The venting of steam and ingestion of air shall be minimized with the design directed toward full vapor performance.

7.2.3.3.3 Subcooling shall generally be prevented.

7.2.3.3.4 Condensate shall be returned to boilers or source devices at the highest possible temperature.

7.2.3.4 Water Systems

7.2.3.4.1 Design flow quantity shall be minimized by designing for the maximum practical temperature differential.

7.2.3.4.2 Flow quantity shall be varied with load where possible.

7.2.3.4.3 Designs shall be for lowest practical pressure rise (or drop).

7.2.3.4.4 Operating and idle control modes shall be provided.

7.2.3.4.5 When locating equipment, the critical pressure path shall be identified and the runs sized for minimum practical pressure drop.

7.2.3.5 Air Systems

7.2.3.5.1 Air flow quantity shall be minimized by careful load analysis and an effective distribution system. If the psychometric nature of the application allows, the supply air quantity shall vary with the sensible load (i.e., VAV systems). The fan pressure requirement shall be held to the lowest practical value. Fan pressure shall be avoided as a source for control power.

7.2.3.5.2 Each fan system shall be designed and controlled to reduce mechanical cooling requirements by taking advantage of favorable weather conditions.

7.2.3.5.3 ''Normal'' and ''idle'' control modes shall be provided for the fan systems as well as the psychometric systems.

7.2.3.5.4 Duct run distances shall be as short as possible, and the runs on the critical pressure path sized for minimum practical pressure drop.

7.2.4 Radiant Heating

7.2.4.1 Radiant heating systems shall be considered in lieu of convective or all-air heating systems to heat areas which experience infiltration loads in excess of two (2) air changes per hour at design heating conditions.

7.2.4.2 Radiant heating systems should be considered for areas with high ceilings, for spot heating, and for other applications where radiant heating may be more energy efficient than convective or all-air heating systems.

7.2.5 Energy Recovery

7.2.5.1 Systems that recover energy should be considered when rejected fluid is of adequate temperature and a simultaneous need for energy exists for a significant number of operating hours.

7.3 Minimum Requirements

7.3.1 Calculation Procedures

7.3.1.1 Heating and cooling system design loads for the purpose of sizing systems and equipment shall be determined in accordance with the procedures described in the *ASHRAE Handbook, 1985 Fundamentals Volume,* or a similar computation procedure. The design parameters specified in sections 7.3.1.2 through 7.3.1.10 shall be used for calculational purposes only and are not requirements or recommendations for operating setpoints.

7.3.1.2 *Indoor Design Conditions.* Indoor design temperature and humidity conditions for general comfort applications shall be in accordance with the comfort criteria established in *ANSI/ASHRAE Standard 55–1981,* ''Thermal Environmental Conditions for Human Occupancy,'' and/or Chapter 8 of the *ASHRAE Handbook, 1985 Fundamentals Volume,* except that winter humidification and summer dehumidification are not required.

7.3.1.2.1 *Exceptions to Section 7.3.1.2:*

(a) Health care institutions and similar facilities where the indoor conditions may not be appropriate for the health and safety of occupants; and

(b) Where special room temperature and/or humidity conditions are required by a process or procedure, other than comfort, such as rooms used for surgery or data processing.

7.3.1.3 *Outdoor Design Conditions.* Outdoor design conditions shall be selected for listed locations from the *ASHRAE Handbook, 1985 Fundamentals Volume,* from the columns of 99% values for heating design and 2.5% values for cooling design. Local weather data from the National Weather Service of the National Oceanic and Atmospheric Administration based on the same 99% and 2.5% values (or statistically similar annualized values such as 0.2% winter and 0.5% summer) may be used.

7.3.1.3.1 *Exception to Section 7.3.1.3:*

(a) Where necessary to assure the prevention of damage to the building or to material and equipment within the building, the median of annual extremes for heating and 1% column for cooling may be used.

7.3.1.4 *Ventilation.* Outdoor air ventilation rates shall be selected from section 6.1 of *ASHRAE Standard 62–1981,* ''Ventilation for Acceptable Indoor Air Quality.''

7.3.1.4.1 *Exception to Section 7.3.1.4:*

(a) Outdoor air quantities, exceeding those shown in *ASHRAE Standard 62–1981,* required because of special occupancy or process requirements, source control of air contamination, or local codes.

7.3.1.5 *Infiltration.* Infiltration for heating and cooling design loads shall be calculated by the procedures in the *ASHRAE Handbook, 1985 Fundamentals Volume,* or a similar computation procedure.

7.3.1.6 *Envelope.* Building envelope heating and cooling loads shall be based on envelope characteristics, such as thermal conductance, shading coefficient and air leakage, consistent with the values used in the proposed building design to demonstrate compliance with section 5.0.

7.3.1.7 *Lighting*. Lighting loads shall be based on proposed design lighting levels or power budgets consistent with section 3.0. Lighting may be ignored for heating load calculations.

7.3.1.8 *Other Loads*. Other HVAC system loads, such as those due to people and equipment, shall be based on design data compiled from at least one of the following sources:

7.3.1.8.1 Actual information based on the intended use of the building;

7.3.1.8.2 Published data from manufacturers' technical publications and from technical society publications such as the *ASHRAE Handbook, 1987 HVAC Systems Applications Volume;*

7.3.1.8.3 Alereza, ''Estimates of Recommended Heat Gains Due to Commercial Appliances and Equipment,'' *ASHRAE Transactions 90 (Pt. 2A), 25–28* (1984);

7.3.1.8.4 Default values to be used in determining the design energy budget in section 11.0 or 12.0 taken from Tables 11–2, 11–3, 11–4 and 11–6; and

7.3.1.8.5 Other data based on designer's experience of expected loads and occupancy patterns.

7.3.1.8.6 *Exception to Section 7.3.1.8:*

(a) Internal heat gains may be ignored for heating load calculations.

7.3.1.9 *Safety Factor*. Design loads may, at the designer's option, be increased by as much as 10% to account for unexpected loads or changes in space usage.

7.3.1.10 *Pick-up Loads*. Transient loads such as warm-up or cool-down loads that occur after off-hour setback or shutoff, may be calculated from basic principles, based on the heat capacity of the building and its contents, the degree of setback, and desired recovery time, or may be assumed to be up to 30% for heating and 10% for cooling of the steady-state design loads.

7.3.2 System and Equipment Sizing

7.3.2.1 HVAC systems and equipment shall be sized to provide no more than the space and system loads require, as calculated in accordance with section 7.3.1.

7.3.2.1.1 *Exceptions to Section 7.3.2.1:*

(a) Equipment capacity may exceed the design load if the equipment selected is the smallest size needed to meet the load within available options of equipment;

(b) Equipment whose capacity exceeds the design load may be specified if calculations demonstrate that oversizing can be shown not to increase annual energy use;

(c) Stand-by equipment may be installed if controls and devices are provided that allow stand-by equipment to operate automatically only when the primary equipment is not operating;

(d) Multiple units of the same equipment type, such as multiple chillers and boilers, with combined capacities exceeding the design load may be specified to operate concurrently only if controls are provided that sequence or otherwise optimally control the operation of each unit based on cooling or heating load;

(e) For unitary equipment with both heating and cooling capability, only one function, either the heating or the cooling, need meet the requirements of this subsection. Capacity for the other function shall be, within available equipment options, the smallest size necessary to meet the load; and

(f) For buildings complying with section 11.0 or 12.0, equipment of higher capacity than the design load may be specified if the oversized equipment is modeled in the building energy analysis of the proposed design and the proposed design complies with the standards.

7.3.3 Separate Air Distribution Systems

7.3.3.1 Zones in a building that are expected to operate non-concurrently for 750 or more hours per year shall either be served by separate air distribution systems, or off-hour controls shall be provided in accordance with section 7.3.5.3.

7.3.3.2 Zones with special process temperature and/or humidity requirements shall be served by separate air distribution systems from those serving zones requiring only comfort heating and/or cooling, or supplementary provisions shall be included to allow the primary systems to be specifically controlled for comfort purposes only.

7.3.3.2.1 *Exception to Section 7.3.3.2:*

(a) Zones, requiring comfort heating and/or cooling, that are served by a system primarily used for process temperature and humidity control, need not be served by a separate system if the total supply air to these zones is no more than 25% of the total system supply air, or the zones total conditioned floor area is less than 1000 ft^2.

7.3.3.3 Zones having substantially different heating or cooling load characteristics, such as perimeter zones in contrast to interior zones, shall not be served by a single multiple zone air distribution system.

7.3.4 Temperature Controls

7.3.4.1 *System Control.* Each HVAC system shall include at least one temperature control device.

7.3.4.2 *Zone Controls.* The supply of heating and/or cooling energy to each zone shall be controlled by an individual thermostat located within the zone.

7.3.4.2.1 *Exceptions to Section 7.3.4.2:*

(a) Independent perimeter systems may serve multiple zones of the primary/interior system with the following limitations:

(1) The perimeter system shall include at least one thermostatic control zone for each major building exposure having exterior walls facing only one orientation for 50 contiguous feet or more; and

(2) The perimeter system heating and/or cooling supply shall be controlled by thermostat controls located within the zone(s) served by the system; and

(b) A dwelling unit may be considered a single zone.

7.3.4.3 Zone thermostats used to control comfort heating shall be capable of being set, locally or remotely, by adjustment or selection of sensors, down to 55 °F.

7.3.4.4 Zone thermostats used to control comfort cooling shall be capable of being set, locally or remotely, by adjustment or selection of sensors, up to 85 °F.

7.3.4.5 Zone thermostats used to control both heating and cooling shall be capable of providing a temperavure range or dead band of at least 5 °F within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum.

7.3.4.5.1 *Exceptions to Section 7.3.4.5:*

(a) For buildings complying with Section 11.0 or 12.0, dead band controls are not required if, in the building energy analysis, heating and cooling thermostat setpoints are set to the same value between 70 °F and 75 °F and assumed to be constant throughout the year;

(b) Special occupancy, special usage or construction code requirements where dead band controls are not appropriate, adjustable single setpoint thermostats may be used; and

(c) Thermostats that require manual changeover between heating and cooling modes.

7.3.5 Off-hour Controls

7.3.5.1 Each HVAC system shall have automatic control setback and/or shutdown of equipment during periods of non-use or alternate use of the spaces served by the system.

7.3.5.1.1 *Exceptions to Section 7.3.5.1:*

(a) Systems serving areas expected to operate continuously;

(b) Where equipment with a full load demand of 2kW (6826 Btu/h) or less may be controlled by readily accessible manual off-hour controls;

(c) Where setback or shutdown will not result in a decrease in overall building energy use.

7.3.5.2 Outside air supply and/or exhaust systems shall be equipped with motorized or gravity dampers or other means of automatic volume shutoff or reduction during periods of non-use or alternate use of the spaces served by the system.

7.3.5.2.1 *Exceptions to Section 7.3.5.2:*

(a) Individual ventilation systems when design air flow is 3000 cfm or less;

(b) Systems that operate continuously;

(c) When restricted by code, such as at combustion air intakes; or

(d) When gravity and other non-electrical ventilation systems may be controlled by readily accessible manual damper controls.

7.3.5.2.2 Dampers may be required in some climates to prevent equipment damage due to freezing and/or to provide proper warm-up control.

7.3.5.3 Systems that serve areas that operate non-concurrently for 750 or more hours per year shall have isolation devices and controls for shut off or set back of heating and cooling to each zone independently. Isolation is not required for zones expected to operate continuously or expected to be inoperative only when all other zones are inoperative.

7.3.5.3.1 For buildings where occupancy patterns are not known at the time of system design, isolation areas may be predesignated.

7.3.5.3.2 Zones may be grouped into a single isolation area providing the total conditioned floor area does not exceed 25,000 ft^2 per group nor include more than one floor.

7.3.6 Humidity Control

7.3.6.1 If a system maintains specific relative humidities by adding moisture, a humidistat shall be provided.

7.3.6.2 If comfort humidification is provided, the system shall be designed to prevent the use of fossil fuel or electricity to maintain relative humidity in excess of 30%.

7.3.6.3 If comfort dehumidification is provided, the system shall be designed to prevent the use of fossil fuel or electricity to reduce relative humidity below 60%.

7.3.7 Materials and Construction

7.3.7.1 Insulation required by section 7.3.7.2 and 7.3.7.3 shall be suitably protected from damage. Insulation shall be installed in accordance with the *Midwest Insulation Contractors Association ''Commercial and Industrial Insulation Standards,''* 1983.

7.3.7.2 *Piping Insulation*. All HVAC system piping installed to serve buildings and within buildings shall be thermally insulated in accordance with Table 7.3–1.

Table 7.3-1
Minimum Pipe Insulation (In.)[1]

Fluid Design Operating Temperature Range, °F	Insulation Conductivity		Nominal Pipe Diameter (In.)					
	Conductivity Range Btu·in./F·h·ft[2]	Mean Rating Temperature °F	Runouts[2] up to 2	1 and less	1-1/4 to 2	2-1/2 to 4	5 & 6	8 and up
Heating Systems (Steam, Steam Condensate, & Hot Water)								
351-450	0.32-0.34	250	1.5	2.5	2.5	3.0	3.5	3.5
251-350	0.29-0.31	200	1.5	2.0	2.5	2.5	3.5	3.5
201-250	0.27-0.30	150	1.0	1.5	1.5	2.0	2.0	3.5
141-200	0.25-0.29	125	0.5	1.5	1.5	1.5	1.5	1.5
105-140	0.24-0.28	100	0.5	1.0	1.0	1.0	1.5	1.5
Domestic and Service Hot Water Systems[3]								
105-140	0.24-0.28	100	0.5	1.0	1.0	1.5	1.5	1.5
Cooling Systems (Chilled Water, Brine, & Refrigerant)[4]								
40-55	0.23-0.27	75	0.5	0.5	0.75	1.0	1.0	1.0
Below 40	0.23-0.27	75	1.0	1.0	1.5	1.5	1.5	1.5

1. For minimum thicknesses of alternative insulation types, see Section 7.3.7.2.2.
2. Runouts to individual terminal units not exceeding 12 ft in length.
3. Applies to recirculating sections of service or domestic hot water systems and first 8 ft from storage tank for non-recirculating systems.
4. The required minimum thicknesses do not consider water vapor transmission and condensation. Additional insulation and/or vapor retarders may be required to limit water vapor transmission and condensation.

7.3.7.2.1 *Exceptions to Section 7.3.7.2:*

(a) For manufacturer installed piping within HVAC equipment tested and rated in accordance with Section 8.3;

(b) For piping conveying fluids at temperatures between 55 °F and 105 °F;

(c) For piping conveying fluids that have not been heated or cooled through the use of fossil fuels or electricity; and

(d) When calculations demonstrate that heat gain and/or heat loss to or from piping without insulation will not increase building energy use.

7.3.7.2.2 *Alternative Insulation Types.* Insulation thicknesses in Table 7.3–1 are based on insulation with thermal conductivities listed in Table 7.3–1 for each fluid operating temperature range, rated in accordance with *ASTM C 335–84,* ''Test Method for Steady-State Heat Transfer Properties of Horizontal Pipe Insulations,'' at the mean temperature listed in the table. For insulating materials having conductivities more than of those shown in the Table 7.3–1 for the applicable fluid operating temperature range and at the mean rating temperature shown, when rounded to the nearest 1/100th Btu/h•°F•ft², the minimum thickness shall be determined in accordance with Equation 7.3–1:

$$T = PR \times [(1 + t/PR)^{K}/k - 1]$$

Equation 7.3–1

Where:

T=minimum insulation thickness for material with conductivity K, in.
PR=pipe actual outside radius, in.
t=insulation thickness from Table 7.3–1, in.
K=conductivity of alternate material at the mean rating temperature indicated in Table 7.3–1 for the applicable fluid temperature range, Btu• in./h•°F•ft²
k=the lower value of conductivity listed in Table 7.3–1 for the applicable fluid temperature range, Btu• in./h•°F•ft²

7.3.7.3 *Air Handling System Insulation*. All air handling ducts, plenums, and other enclosures installed as part of an HVAC air distribution system shall be thermally insulated in accordance with Table 7.3–2 (This table comes from section 1005 of the 1985 Uniform Mechanical Code).

Table 7.3-2
Minimum Duct Insulation

Duct Location	Cooling[2]		Heating[3]	
	Annual Cooling Degree Days Base 65 °F	Insulation R-value[4] $ft^2 \cdot h \cdot {}^oF/Btu$	Annual Heating Degree Days Base 65 °F	Insulation R-value[4] $ft^2 \cdot h \cdot {}^oF/Btu$
Exterior of building	below 500 500 to 1150 1151 to 2000 above 2000	3.3 5.0 6.5 8.0	below 1500 1500 to 4500 4501 to 7500 above 7500	3.3 5.0 6.5 8.0
Inside of building envelope or in unconditioned spaces[7]				
$TD^5 <= 15$		None Requ'd		None Req'd
$40 >= TD^5 > 15$	----	3.3	----	3.3
$TD^5 > 40$	----	5.0[6]	----	5.0[6]

1. Insulation R-values shown are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and condensation. Additional insulation and/or vapor retarders may be required to limit vapor transmission and condensation. For ducts which are designed to convey both heated and cooled air, duct insulation shall be as required by the most restrictive condition. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of this Section or Section 5.0.
2. Cooling ducts are those designed to convey mechanically heated air or return ducts in such systems.
3. Heating ducts are those designed to convey mechanically heated air or return ducts in such systems.
4. Insulation resistance measured on a horizontal plane in accordance with ASTM C518-85 at a mean temperature of 75 °F at the installed insulation thickness.
5. TD is defined as the temperature difference at design conditions (see Section 7.3.1) between the space within which the duct is located and the design air temperature in the duct.
6. Insulation resistance for runnouts to terminal devices less than 10 feet in length need not exceed 3.3 $ft^2 \cdot h \cdot F/Btu$.
7. Unconditioned spaces include crawl spaces and attics.

7.3.7.3.1 *Exception to section 7.3.7.3:* Duct insulation is not required in any of the following cases:

(a) Manufacturer installed plenums, casings or ductwork furnished as a part of HVAC equipment tested and rated in accordance with section 8.3; and

(b) When calculations demonstrate that heat gain and/or heat loss to or from ducts without insulation will not increase building energy use.

7.3.7.4 *Duct Construction.* All air handling ductwork and plenums shall be constructed, erected and tested in accordance with the following Sheet Metal and Air Conditioning Contractors National Association (SMACNA) Standards: *HVAC Duct System Design Manual,* 1986; *HVAC Duct Leakage Test Manual,* 1985; and *Fibrous Glass Construction Standards,* 5th edition, 1979.

7.3.7.4.1 Ductwork designed to operate at static pressure differences greater than 3 in. W.C. shall be leak tested and conform with the following requirements of the *HVAC Duct Leakage Manual, 1985:* Test procedures shall be in accordance with those outlined in section 5.0 of the manual, or equivalent; test reports shall be provided in accordance with section 6.0 of the manual, or equivalent; the tested duct leakage class at a test pressure equal to the design duct pressure class rating shall be equal to or less than leakage class 6 as defined in section 4.1 of the manual. Leakage testing may be limited to representative sections of the duct system but in no case shall such tested sections include less than 25% of the total installed duct area for the designated pressure class.

7.3.7.4.2 Where supply ductwork designed to operate at static pressure differences from ¼ in. to 2 in. W.C. are located outside of the conditioned space, including return plenums, joints shall be sealed in accordance with Seal Class C, as defined in the SMACNA manuals referenced above. Pressure sensitive tape shall not be used as the primary sealant for such ducts designed to operate at 1 in. W.C. pressure difference or greater.

7.3.8 Completion Requirements

7.3.8.1 An operating and maintenance manual shall be provided to the building owner. The manual shall include basic data relating to the operation and maintenance of HVAC systems and equipment. Required routine maintenance actions shall be clearly identified. Where applicable, HVAC controls information such as diagrams, schematics, control sequence descriptions, and maintenance and calibration information shall be included.

7.3.8.2 Air system balancing shall be accomplished in a manner to minimize throttling losses and then fan speed shall be adjusted to meet design flow conditions. Balancing procedures shall be in accordance with those established by the National Environmental Balancing Bureau (NEBB), the Association of Air Balancing Council (AABC), or similar procedures.

7.3.8.2.1 *Exception to section 7.3.8.2:*

(a) Damper throttling may be used for air system balancing with fan motors of 1 hp or less, or if throttling results in no greater than ⅓ hp fan horsepower draw above that required if the fan speed were adjusted.

7.3.8.3 Hydronic system balancing shall be accomplished in a manner to minimize throttling losses and then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions.

7.3.8.3.1 *Exceptions to section 7.3.8.3:* Valve throttling may be used for hydronic systems balancing under any of the following conditions:

(a) Pumps with pump motors of 10 hp and less;

(b) If throttling results in pump horsepower draw no greater than 3 hp above that required if the impeller were trimmed;

(c) To reserve additional pump pressure capability in open circuit piping systems subject to fouling. Valve throttling pressure drop shall not exceed that expected for future fouling; or

(d) Where it can be shown that throttling will not increase overall building energy use.

7.3.8.4 HVAC control systems shall be tested to assure that control elements are calibrated, adjusted, and in proper working condition.

7.4 Heating, Ventilation and Air-Conditioning (HVAC) Systems—Prescriptive Compliance Alternative

7.4.1 Zone Controls

7.4.1.1 Zone thermostatic and humidistatic controls shall be capable of operating in sequence, the supply of heating and cooling energy to the zone. The controls shall prevent:

7.4.1.1.1 Reheating (heating air that is cooler than system mixed air);

7.4.1.1.2 Recooling (cooling air that is warmer than system mixed air);

7.4.1.1.3 Mixing or the simultaneous supply of air that has been previously mechanically heated and air that has been previously cooled, either by mechanical refrigeration or by economizer systems; and

7.4.1.1.4 Other simultaneous operation of heating and cooling systems to one zone.

7.4.1.2 *Exceptions to section 7.4.1.1:*

7.4.1.2.1 Variable air volume systems that, during periods of occupancy, are designed to reduce the air supply to each zone to a minimum before reheating, recooling, or mixing during periods of occupancy. The minimum volume setting shall be no greater than the larger of the following:

(a) 30% of the peak supply volume;

(b) The minimum volume required to meet the ventilation requirements of section 7.3.1.4; and

(c) 0.4 cfm/ft^2 of conditioned zone area. In addition, supply air temperatures shall be automatically reset based on representative building loads or outside air temperature by at least 25% of the difference between the design supply air and room air temperature. Zones expected to experience relatively constant loads, such as interior zones, shall be designed for the fully reset supply temperature. Supply air reset control is not required if calculations demonstrate that it increases overall building energy use;

7.4.1.2.2 Zones where special pressurization relationships or cross-contamination requirements are such that variable air volume systems are impractical, such as some areas of hospitals and laboratories. In these cases, systems shall include automatic supply air reset controls in accordance with section 7.4.1.2.1 above;

7.4.1.2.3 At least 75% of the energy for reheating or providing warm air in mixing systems is provided from site-recovered energy that would otherwise be wasted, or from non-depletable energy sources;

7.4.1.2.4 Zones where specific humidity levels are required to satisfy process needs, such as computer rooms and museums (see section 7.3.3.2); and

7.4.1.2.5 Zones with a peak supply air quantity of 300 cfm or less.

7.4.2 Economizer Controls

7.4.2.1 Each fan system shall be designed to take advantage of favorable weather conditions to reduce mechanical cooling requirements. The system shall include either of the following:

7.4.2.1.1 A temperature or enthalpy air economizer system that is capable of automatically modulating outside air and return air dampers to provide up to 85% outside air for cooling; or

7.4.2.1.2 A water economizer system that is capable of cooling supply air by direct and/or indirect evaporation. The system shall be designed and controlled to be able to provide 100% of the system cooling load at outside air temperatures of 50 °F dry-bulb/45 °F wet-bulb and below. Each economizer system shall be capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load.

7.4.2.1.3 *Exceptions to section 7.4.2.1:*

(a) individual fan/cooling units with supply capacity of less than 3,000 cfm or a total cooling capacity less than 90,000 Btu/h. The total capacity of such units per building complying by this exception shall not exceed 600,000 Btu/h per building or 10% of the total installed cooling capacity, whichever is larger;

(b) Systems with air or evaporatively cooled condensers and for which one of the following is true:

(1) The system is located where the quality of the air, as defined in *ASHRAE Standard 62–1981,* is so poor as to require extensive treatment of the air, and

(2) Calculations indicate that the use of outdoor air cooling affects the operation of other systems, such as humidification, dehumidification, and supermarket refrigeration systems and will increase overall building energy use;

(c) Calculations demonstrate that the overall building energy use for alternative designs, such as internal/external zone heat recovery systems, are less than those for an economizer system;

(d) The system is located where the outdoor summer wet-bulb design condition (2.5% occurrence, *ASHRAE Handbook, 1985 Fundamentals Volume)* is more than 72 °F and annual HDD65 are less than 2,000;

(e) Systems that serve envelope dominated spaces whose design space sensible cooling load, excluding transmission and infiltration loads, is less than or equal to transmission and infiltration losses at an outdoor temperature of 60 °F;

(f) Systems serving residential spaces including hotel/motel rooms;

(g) Cooling systems for which 75% of its annual energy consumption is provided by site-recovered energy that would otherwise be wasted, or from non-depletable energy sources; and

(h) The zone(s) served by the system each have operable openings (windows, doors, etc.), the openable area of which is greater than 5% of the conditioned floor area. This exception applies only to spaces open to and within 20 ft of the operable openings. Automatic controls shall be provided that lockout system mechanical cooling when outdoor air temperatures are less than 60 °F.

7.4.2.2 Economizer systems shall be capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load.

7.4.2.2.1 *Exceptions to section 7.4.2.2.*

(a) Direct expansion systems may include controls to reduce the quantity of outside air as required to prevent coil frosting at the lowest step of compressor unloading. Individual direct expansion units that have a cooling capacity of 180,000 Btu/h or less may use economizer controls that preclude economizer operation whenever mechanical cooling is required simultaneously; and

(b) Systems in climates with less than 750 average hours per year between 8 a.m. and 4 p.m. when the ambient dry bulb temperatures are between 55 °F and 69 °F inclusive. See Attachment 5A for climate data for 234 U.S. cities.

7.4.2.3 System design and economizer controls shall be such that economizer operation does not increase the building heating energy use during normal operation.

7.4.2.3.1 *Exception to section 7.4.2.3:*

(a) At least 75% of the energy for heating is provided from site-recovered energy that would otherwise be wasted, or from non-depletable energy sources.

7.4.3 Fan System Design Requirements.

7.4.3.1 The following design criteria apply to all HVAC fan systems used for comfort heating, ventilating and/or cooling. For the purposes of this subsection, the energy demand of a fan is the sum of the demand of all fans that are required to operate at design conditions to supply air from the heating and/or cooling source to the conditioned space(s) and return it back to the source or exhaust it to the outdoors.

7.4.3.1.1 *Exceptions to section 7.4.3.1:*

(a) Systems with total fan system motor horsepower of 10 hp or less;

(b) Unitary equipment for which the energy used by the fan is considered in the efficiency ratings of Section 8.0; and

(c) Total fan energy demand need not include the additional power required by air treatment or filtering systems with final pressure drops in excess of 1 in. W.C.

7.4.3.2 Constant Volume Fan Systems.

7.4.3.2.1 For supply and return fan systems that provide a constant air volume whenever the fans are operating, the power required for the combined fan system at design conditions shall not exceed 0.8 W/cfm of supply air.

7.4.3.3 Variable Air Volume (VAV) Fan Systems.

7.4.3.3.1 For supply and return fan systems that vary system air volume automatically as a function of load, the power required by the motors for the combined system at design conditions shall not exceed 1.25 W/cfm.

7.4.3.3.2 Individual VAV fans with motors 75 hp and larger shall include controls and devices necessary for the fan motor to control demand to no more than 50% of design wattage at 50% of design air volume, based on manufacturer's test data.

7.4.4 Pumping System Design Criteria.

7.4.4.1 The following design criteria apply to all HVAC pumping systems used for comfort heating and/or cooling. For the purposes of this section, the energy demand of a pumping system is the sum of the demand of all pumps that are required to operate at design conditions to supply fluid from the heating and/or cooling source to the conditioned space(s) or heat transfer device(s) and return it to the source.

7.4.4.1.1 *Exception to section 7.4.4.1:*

(a) Systems with total pump system motor horsepower of 10 hp or less.

7.4.4.2 *Friction Rate.* Piping systems shall be designed at a design friction pressure loss rate of no more than 4.0 ft of water per 100 equivalent ft of pipe. Lower friction rates may be required for proper noise or corrosion control.

7.4.4.3 *Variable Flow.* Pumping systems that serve control valves designed to modulate or step open and close as a function of load, shall be designed for variable fluid flow. The system shall be capable of reducing flow to 50% of design flow or less. Flow may be varied by one of several methods, including, but not limited to, variable speed driven pumps, staged multiple pumps, or pumps riding their characteristic performance curves.

7.4.4.3.1 *Exceptions to section 7.4.4.3:*

(a) Systems where a minimum flow greater than 50% of the design flow is required for the proper operation of equipment served by the system, such as chillers;

(b) Systems that serve no more than one control valve;

(c) Where the overall building energy use resulting from an alternative design, such as a constant flow/variable temperature pumping system, is no more than those from a variable flow system; and

(d) Systems that include supply temperature reset controls in accordance with section 7.4.5.2 without exception.

7.4.5 System Temperature Reset Controls.

7.4.5.1 *Air Systems.* Systems supplying heated or cooled air to multiple zones shall include controls that automatically reset supply air temperatures by representative building loads or by outside air temperature. Temperature shall be reset by at least 25% of the design supply-air-to-room-air temperature difference. Zones that are expected to experience relatively constant loads, such as interior zones, shall be designed for the fully reset supply temperature.

7.4.5.1.1 *Exceptions to section 7.4.5.1:*

(a) Systems which comply with section 7.4.1 without using exceptions in sections 7.4.1.2.1 or 7.4.1.2.2; and

(b) Where it can be shown that supply air temperature reset increases overall building annual energy costs.

7.4.5.2 *Hydronic Systems.* Systems supplying heated and/or chilled water to comfort conditioning systems shall include controls that automatically reset supply water temperatures by representative building loads (including return water temperature) or by outside air temperature. Temperature shall be reset by at least 25% of the design supply-to-return water temperature difference.

7.4.5.2.1 *Exceptions to section 7.4.5.2:*

(a) Systems that comply with section 7.4.4.3 without exception;

(b) Where it can be shown that supply temperature reset increases overall building annual energy use;

(c) Systems for which supply temperature reset controls cannot be implemented without causing improper operation of heating, cooling, humidification, or dehumidification systems; or

(d) Systems with less than 600,000 Btu/h design capacity.

§ 435.108 Heating, ventilation and air-conditioning (HVAC) equipment.

8.1 General

8.1.1 This section contains minimum requirements for fundamental to good practice and/or the minimum acceptable state-of-the-art in energy efficient HVAC equipment.

8.1.2 A building shall be considered in compliance with this section if the minimum requirements of Section 8.3 are met.

8.2 Principles of Design

8.2.1 The rate of energy input(s) and the heating or cooling output(s) of all HVAC products shall be ascertained. This information shall be based on equipment in new condition, and shall cover full load, partial load, and standby conditions. The information shall also include performance data for modes of equipment operation and at ambient conditions as specified in the